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Leafy, Floral, and Succulent Vegetables

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I. INTRODUCTION

This chapter covers vegetable crops whose edible portion consists of leaves, shoots, buds, or floral organs (Table 1). Basically, most leafy greens, succulent crops, and immature flower heads are included in this category. This group of vegetables represents a taxonomically diverse number of families of which two, the Compositae and Cruciferae, contain many of the most important species (Table 2). Consumption of this group of vegetables has been increasing because of their low caloric value, along with their generally high levels of minerals and vitamins (Table 3). The leafy greens contain particularly high levels of vitamins A and C.

Leafy vegetables are characterized by a large surface-to-volume ratio (Table 4). Because of this feature, they usually have high rates of transpiration. They thus lose water easily and are highly subject to shriveling and wilting. Also, because of the large leaf surface, they are most effectively precooled by vacuum cooling. Hydrocooling is also a satisfactory method to quickly remove the field heat. Succulent crops and immature flower heads, such as artichoke (*Cynara scolymus* L.), asparagus (*Asparagus officinalis* L.), bean sprouts [*Vigna radiata* (L.) R. Wilcz.], broccoli (*Brassica oleracea* L. Botrytis Group), and cauliflower (*Brassica oleracea* L., Botrytis Group), also lose water readily; therefore, they should be stored in an environment with high relative humidity.

The leafy, floral, and succulent vegetable crops are harvested almost exclusively by hand and are commonly packed in the field on mobile packing lines called ''mule trains'' (Table 5). Harvest maturity is most commonly judged by size, as well as density of heading

Table 1 Classification of Leafy, Floral, and Succulent Vegetables on the Basis of Their Primary Edible Plant Part

I. Leaves and associated parts
  A. Leaf blade—chard, endive, leaf lettuce, spinach
  B. Petiole—celery, rhubarb
  C. Bud—brussels sprouts, cabbage, head lettuce
  D. Shoot—green onion, leeks
II. Stems—asparagus
III. Immature flowers—artichoke, broccoli, cauliflower

crops (e.g., iceberg lettuce, *Lactuca sativa* L.) and compactness of immature floral crops (e.g., broccoli and cauliflower).

The storage temperatures of these vegetables need to be low in order to retard the growth of microorganisms, which cause decay rapidly under warm and humid conditions (Table 6). Physiological disorders of leafy, floral, and succulent vegetables are primarily related to such preharvest conditions as mineral deficiencies (Table 7). Most of the crops in this group are of temperate origin and are not susceptible to chilling injury (CI). Their

Table 2 Taxonomic Classification of Some Leafy, Floral, and Succulent Vegetables

Common name	Genus and species
Amaryllidaceae	
Green onion	*Allium cepa*
Leek	*Allium ampeloprasum*
Chenopodiaceae	
Beet greens	*Beta vulgaris*
Spinach	*Spinacia oleracea*
Swiss chard	*Beta vulgaris* Cicla group
Compositae	
Artichoke	*Cynara scolymus*
Chicory, Witloof chicory	*Cichorium intybus*
Endive and escarole	*Cichorium endiva*
Lettuces	*Lactuca sativa*
Cruciferae	
Broccoli	*Brassica oleracea* Botrytis Group
Brussels sprouts	*Brassica oleracea* Gemmifera Group
Cauliflower	*Brassica oleracea* Botrytis Group
Cabbage	*Brassica oleracea* Capitata Group
Chinese cabbage	*Brassica rapa* Pekinensis Group
Collards and kale	*Brassica oleracea* Acephala Group
Kohlrabi	*Brassica oleracea* Gongylodes Group
Mustard greens	*Brassica juncea*
Turnip greens	*Brassica rapa* Rapifera Group
Watercress	*Nasturtium officinale*
Umbelliferae	
Celery	*Apium graveolens* var. *dulce*
Parsley	*Petroselinum crispum*

Table 3 Composition of Leafy, Floral, and Succulent Vegetables (Amount per 100-g Edible Portion Raw Product)

							Vitamins	
Vegetable	Water (%)	Calories	Protein (g)	Fat (g)	Ca (mg)	K (mg)	A (IU)	C (mg)
Artichokes	84.38	51	2.66	0.20	48	339	185	10.8
Asparagus	92.25	22	3.06	0.22	22	302	897	33.0
Bean sprouts	90.40	30	3.04	0.18	13	149	21	13.2
Broccoli	90.69	28	2.98	0.35	48	325	1,542	93.2
Brussels sprouts	86.00	43	3.38	0.30	42	389	883	85.0
Cabbage, common	92.52	24	1.21	0.18	47	246	126	47.3
Cabbage, Chinese								
Napa	94.39	16	1.20	0.20	77	238	1,200	27.0
Pak choi	95.32	13	1.50	0.20	105	252	3,000	45.0
Cauliflower	92.26	24	1.99	0.18	29	355	16	71.5
Celery	94.70	16	0.66	0.12	36	284	127	6.3
Collards	93.90	19	1.57	0.22	117	148	3,330	23.3
Endive	93.79	17	1.25	0.20	52	314	2,050	6.5
Kale	84.46	50	3.30	0.70	135	447	8,900	120.0
Kohlrabi	91.00	27	1.70	0.10	24	350	36	62.0
Leeks	83.00	61	1.50	0.30	59	180	95	12.0
Lettuce, crisphead	95.89	13	1.01	0.19	19	158	330	3.9
Lettuce, romaine	94.91	16	1.62	0.20	36	290	2,600	24.0
Mustard greens	90.80	26	2.70	0.20	103	354	5,300	70.0
Onions, green	91.91	25	1.74	0.14	60	257	5,000	45.0
Parsley	88.31	33	2.20	0.30	130	536	5,200	90.0
Spinach	91.58	22	2.86	0.35	99	558	6,715	28.1
Turnip greens	91.07	27	1.50	0.30	190	296	7,600	60.0
Watercress	95.11	11	2.30	0.10	120	330	4,700	43.0

Source: Haytowitz and Matthews, 1984.

Table 4 Surface-to-Volume Ratios of Some Edible Plant Materials

Surface/volume ratio ($cm^2 cm^{-3}$)	Plant material
500–1,000	Edible leaves (intercellular surface)
50–100	Individual edible leaves (exposed surface); very small grains (e.g., teff)
10–15	Most cereal grains
5–10	Leguminous seeds; smaller soft fruits (e.g., currants)
2–5	Leguminous fruits; nuts (except coconut); larger soft fruits (e.g., strawberry); rhubarb; shallot
0.5–1.5	Tubers; tuberous roots (except, e.g., large yams); tap roots (except, e.g., large Swede turnips); pome, stone, and citrus fruits; cucurbitous fruits (except, e.g., large marrows); banana; onion
0.2–0.5	Densely packed cabbage (e.g., cv. Decema); large Swede turnips and yams; coconut

Source: Burton, 1982.

Table 5 Generalized Postharvest Handling Procedure for Leafy, Floral, and Succulent Vegetables

Step	Function
1	Harvesting mostly by hand; some harvesting aids are in use.
2	Transport to packinghouse and unloading if not field packed
3	Cutting and trimming (by harvester or by different worker on mobile packing line or in packinghouse)
4	Sorting and manual sizing (as above)
5	Washing or rinsing
6	Wrapping (e.g., cauliflower, head lettuce) or bagging (e.g., celery)
7	Packing in shipping containers (waxed fiberboard or plastic to withstand water or ice exposure for cooling)
8	Palletization of shipping containers
9	Cooling methods
	1 Vacuum cooling: lettuce
	2 Hydrovacuum cooling: cauliflower, celery
	3 Hydrocooling: artichoke, celery, green onions, leaf lettuce, leek, spinach
	4 Package ice: broccoli, parsley, spinach
	5 Room cooling: artichoke, cabbage
10	Transport, destination handling, retail handling

Table 6 Common Diseases of Leafy, Floral, and Succulent Vegetables

Disease	Vegetables
Bacterial soft rot	Asparagus, celery, chard, lettuce, spinach
Big vein	Lettuce
Downy mildew	Lettuce, spinach
Gray mold rot	Artichoke, celery, lettuce, rhubarb
Rhizoctonia	Cabbage
Watery soft rot	Cabbage, celery, lettuce

Table 7 Physiological Disorders of Leafy, Floral, and Succulent Vegetables

Freezing injury (preharvest and postharvest)
Chilling injury of asparagus
Solar injury (browning) of cauliflower
Tipburn of cabbage, brussels sprouts, lettuce—calcium deficiency related
Bolting (development of seedstalks) in lettuce and leek
Pithiness of celery—a sign of senescence
Riciness of cauliflower—a sign of senescence
Blackheart of celery, endive, escarole—calcium deficiency related
Yellowing of green tissues—enhanced by C_2H_4
Physiological disorders of lettuce
Brown stain—caused by CO_2 at 2% or higher at 0–5°C
Russet spotting—caused by C_2H_4 at 0.1 ppm or higher
Rusty-brown discoloration of 'Climax' cultivar—increased by lettuce mosaic virus
Pink rib—a symptom of senescence
Low O_2 injury—caused by exposure to less than 1% O_2

Table 8 Optimal Temperature, Relative Humidity, and Controlled Atmospheres for Storage of Leafy, Floral, and Succulent Vegetable Crops

Commodity	Temp. (°C)	Relative humidity (%)	Controlled atmosphere (%)		Source
			O_2	CO_2	
Artichokes	0	95–100	3	3	Hardenburg et al., 1986; Ryall and Lipton, 1979
Asparagus	0–2	95–100	Air	10–14	Hardenburg et al., 1986; Saltveit, 1993
Bean sprouts	0	95–100	5	15	Lipton et al., 1981; Varoquaux et al., 1996
Broccoli	0	95–100	1–2	5–10	Lipton and Harris, 1974; Saltveit, 1993
Brussels sprouts	0	95–100	2	10	Hardenburg et al., 1986; Lipton and Mackey, 1987
Cabbage, common	0	98–100	2–3	3–6	Hardenburg et al., 1986; Saltveit, 1993
Cabbage, Chinese	0	95–100	1–2	0–5	Hardenburg et al., 1986; Saltveit, 1993
Cauliflower	0	95+	2	5	Hardenburg et al., 1986; Tomkins and Sutherland, 1989
Celery	0	98–100	1.5	7.5	Hardenburg et al., 1986; Reyes and Smith, 1986
Chicory, Witloof	0	95+	3–4	4–5	Ryall and Lipton, 1979; Herregods, 1971
Endive and escarole	0	95–100			Ryall and Lipton, 1979
Kohlrabi	0	98–100			Ryall and Lipton, 1979
Leeks	0	95–100	2	2–5	Goffings and Herregods, 1989; Hruschka, 1978
Lettuce, crisphead	0	98–100	3	2	Ryall and Lipton, 1979
Lettuce, romaine	0	98–100	2–10	5	Aharoni and Ben-Yehoshua, 1973
Onions, green	0	95–100	1	5	Hardenburg et al., 1986; Hruschka, 1974
Parsley	0	95–100	10	11	Apeland, 1971; Hruschka and Wang, 1979
Rhubarb	0	95–100			Hruschka, 1967
Spinach	0	95–100	7–10	5–10	Hardenburg et al., 1986; Saltveit, 1993
Watercress	0	95–100			Hruschka and Wang, 1979

high water content makes them susceptible to freezing injury, however. The recommended temperature for storage of the chilling-insensitive species is 0°C. At this temperature, physiological and pathological deterioration is at a minimum. Some commodities in this group respond favorably to atmospheric modifications, including low O_2 and/or high CO_2. In these cases, a combination of low temperature and modified or controlled atmosphere (MA and CA) can further improve the maintenance of quality in these commodities after harvest. Information on quality criteria, precooling methods, and packaging is provided. Recommendations for optimal storage with respect to temperature, humidity, atmosphere, and other factors for these vegetables are discussed. Major market diseases affecting the commodities are listed. Table 8 summarizes the recommended temperature, relative humidity (RH), and CA for storage of leafy, floral, and succulent vegetable crops.

II. POSTHARVEST PHYSIOLOGY AND HANDLING OF SELECTED LEAFY, FLORAL, AND SUCCULENT VEGETABLES

A. Artichokes (*Cynara scolymus* L.)

The globe artichoke is a perennial of the Asteraceae (Compositae) family (Table 2). A cone of short, thick-stemmed bracts protects the edible portion, which includes the tender immature flower bud and fleshy central base. The outer bracts of an artichoke ready for harvest should be tightly closed, firm, and turgid. A high-quality artichoke should not have browning on the outer bracts or violet discoloration on the inner bracts.

The recommended requirements for commercial storage of artichokes are 0°C temperature and 95–100% RH (Hardenburg et al., 1986). Artichoke buds can be kept in good condition for 2 weeks at 0°C, 10 days at 5°C, and only 5 days at 10°C (Ryall and Lipton, 1979). To maintain quality and storage life, the buds should be precooled to below 5°C within 24 h of harvest (Lipton and Stewart, 1963). Hydrocooling or room cooling usually will retard subsequent deterioration, such as discoloration, weight loss, and decay. The occurrence of violet discoloration of inner bracts was found to be low at temperatures below 10°C or above 25°C (Bianco, 1979). This low incidence of discoloration was reported to be correlated with low rates of ethylene production from the buds (Ryder et al., 1983).

The effectiveness of CA in maintaining artichoke quality is apparently dependent upon bud maturity, cultivar, temperature, and the atmosphere used (Andre et al., 1980; Rappaport and Watada, 1958; Ryder et al., 1983). Miccolis and Saltveit (1988) reported that no beneficial effects of CA on quality retention were obtained when artichoke buds were stored at 0°C in low O_2 and/or elevated CO_2. Ryall and Lipton (1979), however, showed that storage quality of artichokes was improved by an atmosphere of 3% O_2 plus 3% CO_2 after 1 month of storage at 1.5°C. Andre et al. (1980) detected an improvement in storage quality over air storage when using a wide range of O_2 (5–15%) and CO_2 (2–7%) atmospheres. Optimal atmospheres were found to vary with different cultivars. For example, the best atmospheres for storage of 'Violeta' were found to be 1–2% O_2 plus 3–4% CO_2, while the best storage atmospheres for 'Blanca de Tudela' were 2% O_2 plus 6% CO_2 or 5–6% O_2 plus 3–4% CO_2 (Escriche et al., 1982). Reduction of browning of the bracts is the main advantage gained from CA storage.

Splitting of the bract tip is a common problem caused by rough handling during harvesting, transportation, and packing. The surfaces of the bracts can also be easily bruised and scratched. The abraded areas usually turn brown or black, which detracts from the appearance and quality, and provides a route through which decay organisms can enter. The most common decay is gray mold rot (*Botrytis cinerea*) (Moline and Lipton, 1987). The lesions most frequently start on wounds and spread to other areas of the bud. Since low temperature slows the spread of the disease, fungus growth near freezing temperature is minimal. Low temperatures therefore must be maintained throughout the postharvest period of artichokes.

B. Asparagus (*Asparagus officinalis* L.)

Both white asparagus and green asparagus are produced in various parts of the world, even though green asparagus is preferred in markets in the United States. White asparagus spears grown under black plastic mulch tend to suffer less freeze damage than green asparagus grown without cover (Makus et al., 1994). Quality criteria for green asparagus and white asparagus are virtually the same, however, with the exception of color.

A good quality asparagus spear should be straight and turgid. The bracts on the side and the tip of the spear should be tightly closed. Excessive fiber content and fiber lignification contribute to spear toughness, which is the major textural problem of asparagus after harvest. Prompt cooling after harvest, holding cut ends in water, glyphosate application, MA or CA storage, and hypobaric storage have been reported to reduce toughness, retain tenderness, and prevent increase in fiber and lignin content (Chang, 1987; Dilley, 1977; Everson et al., 1992; Isenberg, 1979; Ketsa and Piyasaengthong, 1994b; Lipton, 1990; Lougheed and Dewey, 1966; Saltveit, 1988).

Asparagus deteriorates very rapidly at warm temperatures after cutting (Lill et al., 1990). Loss of flavor and tenderness, degradation of nutritional value, and development of decay occur within a short time at high temperatures. A delay in cooling for more than 4 h results in large increases in shear force value, a measurement of toughness (Hernández-Rivera et al., 1992). A significant loss of soluble carbohydrates and proteins from tip segments also takes place at 20°C (King et al., 1988). The spears should therefore be hydrocooled soon after harvest to 4°C or below. For storage of 10 days or less, 0°C is recommended (Hardenburg et al., 1986). For longer storage, however, 2°C should be used because asparagus is subject to CI during prolonged storage at 0°C. Asparagus can be kept successfully for about 3 weeks at 2°C with an RH of 95–100%. High humidity is important to prevent moisture loss, particularly from the cut surface. Loss of water can be minimized by placing the butt end of the asparagus on wet pads or by prepackaging spears in plastic film bags. The bags should be perforated to avoid accumulation of CO_2 and ethylene, because ethylene may induce isoperoxidase changes during fiber formation and adversely affect the quality (Haard et al., 1974).

Asparagus has one of the highest respiration rates among all vegetables (Lipton, 1990). Apical tissue has a higher respiration rate than basal tissue (Saltveit and Kasmire, 1985), which reflects a gradient in metabolic activity along the spear. Strong gradients of sugars and proteins also exist along the spear, with low levels of sugars and high levels of proteins present in the spear tips. The respiration rate is greatly affected by temperature. It increases 10-fold between 0–30°C—from 80 to 865 mg CO_2 $kg^{-1}h^{-1}$ (Lipton, 1990). A strong negative correlation was found between accumulated respiratory activity after harvest and the shelf life of stored asparagus (Brash et al., 1995). Ethylene production by asparagus increases with time after harvest. It increases about 50% between 45 and 165 min after cutting the spears (Haard, 1974). This increase may be a response to the wounding associated with harvest.

Controlled atmosphere is beneficial to asparagus because it retards bacterial soft rot, prevents toughening, water loss, and chlorophyll degradation, and retains more sugars, organic acids, and soluble proteins (Baxter and Waters, 1991; Isenberg, 1979; King et al., 1986; Lougheed and Dewey, 1966; Wang et al., 1971). Low O_2 is not as effective as high CO_2 in the retention of asparagus quality (Lipton, 1965; 1968). Elevated levels of CO_2 at 10–14% are recommended when storage temperature is 0–3°C, whereas 5–9% CO_2 is recommended when storage temperature is 3–6°C (Klieber and Wills, 1992; Saltveit, 1993).

Chilling injury in asparagus may occur when spears are held at 0°C for more than 10 days (Hardenburg et al., 1986). When chilling temperature is combined with high CO_2 (20% or more), CI may occur after only 1 week (Lipton, 1965). Symptoms of CI are flaccidity and a dull, dark gray-green tip (Lipton, 1990). Asparagus should be kept at 2°C for prolonged storage to prevent CI (Ryall and Lipton, 1979).

Several diseases attack asparagus during the postharvest period (Smith et al., 1982). The most serious market disease is bacterial soft rot (*Erwinia carotovora*). This pathogen can enter asparagus tissues through wound areas such as cut ends or mechanical injury. It can also occur at the tips of spears. The rot is soft, watery, and develops an offensive odor in the advanced stages. The best defense against this disease is handling carefully to avoid mechanical injury, cooling promptly to below 4°C, and maintaining cool temperatures throughout the marketing period. Treatment with chlorinated water (100 to 400 ppm) has been reported to reduce bacterial soft rot (Ketsa and Piyasaengthong, 1994a). Other important diseases affecting asparagus include Fusarium rot (*Fusarium oxysporum*), gray mold rot (*Botrytis cinerea*), Phytophthora rot (*Phytophthora* spp.), and watery soft rot (*Sclerotinia sclerotiorum*) (Smith et al., 1982).

C. Bean Sprouts [*Vigna radiata* (L.) R. Wilcz.]

Mung bean sprouts can be harvested within 4 to 6 days after germination. The sprouts are usually grown in the dark at 21–28°C with 95–100% RH. Desirable sprouts ready for market should be around 6 cm in length, turgid, and white without dark streaks or other discolorations. The bean sprouts should be intact without bruises or mechanical damage such as broken hypocotyls or separation of cotyledons.

The sprouts are highly perishable and store best at 0°C with 95–100% RH. Storage life at this condition is about 7 to 9 days (Hardenburg et al., 1986). The rate of respiration increases sharply with temperature from 23 mg $kg^{-1}h^{-1}$ CO_2 at 0°C to 96 mg $kg^{-1}h^{-1}$ CO_2 at 10°C (Lipton et al., 1981). Similarly, ethylene production increases from 0.15 μL $kg^{-1}h^{-1}$ at 0°C to 0.90 μL $kg^{-1}h^{-1}$ at 10°C. Storage life also decreases linearly with the increase in temperature to 2.5 days at 10°C. Symptoms of deterioration are dark streaks on hypocotyls, discoloration of radicles and cotyledons, and development of sliminess, decay, and off-odor.

Film packaging is helpful in reducing moisture loss and maintaining the quality of mung bean sprouts (Tajiri, 1979). Because of their high respiration rates, bean sprouts have to be packaged in microperforated or microporous films (Day, 1990). Films that have adequate permeability to O_2 and CO_2 can create a proper MA within the package, thus prolonging the storage life and prohibiting bacterial growth. Varoquaux et al. (1996) found that films with a permeability of 50,000 ml $O_2 m^{-2} day^{-1} atm^{-1}$ provided the optimal atmosphere composition of 5% O_2 plus 15% CO_2 for bean sprouts stored at 8°C.

Maintenance of a sanitary environment is important throughout the postharvest period, especially for a bacteria-prone product such as bean sprouts. Aerobic microorganisms and lactic acid bacteria (e.g., *Leuconostoc* species) can develop rapidly in bean sprouts under warm temperatures (Varoquaux et al., 1996), therefore maintaining low temperatures and good sanitation practices are essential for handling bean sprouts.

D. Broccoli (*Brassica oleracea* L. Botrytis Group)

A good quality broccoli should have firm, compact clusters of small flower buds. These florets should be tightly closed with dark green color. Some cultivars have a purplish cast over the green surface. Stems should not be too long or thick or discolored. Enlarged or open florets or spread bud clusters are indications of overmaturity and are undesirable for the market. Broccoli provides a good source of vitamins A and C (Table 3), as well as being high in fiber and minerals, including calcium, iron, and potassium (Haytowitz and Matthews, 1984). Broccoli also contains a chemical called sulforaphane, which can trigger increased production of special enzymes in human cells to neutralize cancer-causing agents and which may be linked to the prevention of lung, bladder, and digestive tract cancers.

Broccoli is highly perishable. At room temperature (20–25°C), broccoli turns yellow in 2 to 3 days after harvest under ambient atmospheres (Lieberman and Hardenburg, 1954). Rapid cooling after harvest is essential to inhibit metabolic activities and maintain good quality. Several precooling methods have been reported to be effective in promptly cooling broccoli down to below 2°C, including hydrocooling, top icing, package icing, and liquid icing (Gillies and Toivonen, 1995; Mitchell, 1992). Maintaining the temperature of broccoli near 0°C throughout the postharvest period is important; otherwise it can deteriorate rapidly.

Overwrapping broccoli in perforated film packaging is effective in reducing water loss by maintaining high humidity in the microenvironment within the package (Anelli et al., 1984; Rygg and McCoy, 1952; Wang and Hruschka, 1977). Combined with refrigeration (0°C), proper packaging can retain turgidity and freshness of broccoli for 4 weeks or more (Wang and Hruschka, 1977). Modified atmosphere packaging has also been shown to reduce the degradation of polyunsaturated fatty acids and soluble proteins (Zhuang et al., 1994) and retain higher ascorbic acid content (Rygg and McCoy, 1952). Wrapping broccoli in sealed packages or inadequate air circulation in the storage environment can lead to the development of a strong, offensive odor due to suboxidation caused by low O_2 and high CO_2 concentrations in the atmosphere surrounding the broccoli (Ballantyne et al., 1988; Kasmire et al., 1974). A number of volatile compounds produced by broccoli under anaerobic conditions have been identified (Forney et al., 1991; Hansen et al., 1992). Two of the compounds, methanethiol and dimethyl trisulfide, were thought to be the major sulfurous compounds responsible for the offensive odor (Forney et al., 1991; Hansen et al., 1993). The production of methanethiol by broccoli was initiated within 1 h after O_2 concentration dropped to 0.5% (Obenland et al., 1994).

Broccoli is relatively tolerant to low O_2 and high CO_2 injuries, particularly compared to cauliflower, a closely related vegetable (Lipton and Harris, 1974; 1976). The use of CA storage is therefore beneficial to quality keeping of broccoli. Many studies have shown that CA storage retards yellowing and toughening and prevents mold growth at various temperatures (Aharoni et al., 1985; Bastrash et al., 1993; Isenberg, 1979; Lebermann et al., 1968a; 1968b; Lipton and Harris, 1974; Makhlouf et al., 1989; Wang, 1979). Controlled atmosphere storage also delays the breakdown of membrane phospholipids and thylakoid integrity, and retards the increase of free sterol:phospholipid ratio (Deschene et al., 1991;

Makhlouf et al., 1990). Because of the risk of off-odor when O_2 is below 1% and CO_2 is above 10%, the recommended gas concentrations for CA storage are 1–2% O_2 plus 5–10% CO_2 (Ryall and Lipton, 1979; Saltveit, 1993).

Yellowing of broccoli is accompanied and preceded by a number of physiological and compositional changes, including changes in respiration and ethylene production and losses of sugars, organic acids, and proteins (King and Morris, 1994a, 1994b). Because chloroplast function changes rapidly after harvest, using chlorophyll fluorescence as a nondestructive indicator of freshness in broccoli has been suggested (Toivonen, 1992).

Ethylene plays an important role in the yellowing process of broccoli after harvest (King and Morris, 1994b; Tian et al., 1994). Applications of inhibitors of ethylene biosynthesis or ethylene action such as aminoethoxyvinylglycine, CO_2, 2,5-norbornadiene, and silver ions delay chlorophyll loss in broccoli (Aharoni et al., 1985; Hyodo et al., 1995; and Wang, 1977). Exogenous application of cytokinin decreases respiration rate and delays yellowing of broccoli (Clarke et al., 1994; Dedolph et al., 1962; Gilbart and Dedolph, 1965; MacLean et al., 1963; Pressman and Palevitch, 1973; Rushing, 1990; Shewfelt et al., 1983; Tian et al., 1995). Other treatments that have been reported to improve green color retention, increase longevity, and maintain market quality of broccoli include ethanol vapor treatment (Corcuff et al., 1996), sucrose supplement (Irving and Joyce, 1995), and misting (Barth et al., 1992).

Broccoli is subject to many of the diseases found in cauliflower (Ramsey and Smith, 1961). The principal disease of broccoli is bacterial soft rot. Other decays that can affect broccoli are gray mold rot, watery soft rot, downy mildew (*Peronospora parasitica*), and Alternaria leaf spot (*Alternaria* spp.). Boron deficiency can cause brown heart, cracked petioles, and brown buds in the heads or flower clusters. This physiological disorder can be corrected by borax application (Ramsey and Smith, 1961).

E. Brussels Sprouts (*Brassica oleracea* L., Gemmifera Group)

The outer leaves of good quality brussels sprouts should be green and tightly overlapping. Leaves should not have black specks or other discolorations. Yellowing of the leaves means old age and detracts from their appearance. The entire head should be compact and firm without large air pockets in between the inner leaves.

Cool weather late in the growing season enhances the flavor and quality of brussels sprouts. They are therefore usually grown for harvest in the late fall and early winter. Harvested brussels sprouts can be effectively cooled with vacuum cooling (Ryall and Lipton, 1979). They store well for 3 to 5 weeks at 0°C, especially when the RH is near 100% (Hardenburg et al., 1986; Lyons and Rappaport, 1959). At temperatures the vegetables would encounter during marketing (i.e., 5–7.5°C), CA of 1–2% O_2 plus 10% CO_2 is beneficial to the quality maintenance of brussels sprouts (Lipton and Mackey, 1987). The O_2 concentration should not be less than 1%, however, otherwise extreme bitterness of the heart leaves could be induced. Film packaging or liners are helpful in reducing moisture loss and bruising (Stewart and Barger, 1963). The film should be perforated to prevent high CO_2 injury or suboxidation. Ethylene concentration as low as 0.5 $\mu L\ L^{-1}$ can accelerate yellowing and abscission of the outer leaves (Hansen and Bohling, 1984). Brussels sprouts should therefore not be stored with ethylene-producing fruits.

Internal browning is a physiological disorder of brussels sprouts. The disorder varies with cultivars and is related to water stress, temperature fluctuations, calcium deficiency, and fast growth (Babik, 1987). It has been suggested that the bitterness in some cultivars of brussels sprouts may be linked to the presence of the glucosinolates, sinigrin and progoitrin (Fenwick et al., 1983). Removal of these two compounds may therefore reduce the bitterness in these cultivars. Brussels sprouts have the same kinds of diseases as cabbage and other cruciferae. The most important market and transit diseases are bacterial soft rot and Alternaria leaf spot (Ramsey and Smith, 1961).

F. Cabbage, Common (*Brassica oleracea* L. Capitata Group)

Cabbage heads should be crisp, firm, and compact. Cabbage should be harvested promptly when the heads are mature and solid. Delaying harvest can result in split heads and an increased incidence of field diseases. The quality criteria for green, red, and Savoy cabbages are similar except for the color. Most cabbages are used as salad, cole slaw, and cooked vegetable. A great deal is also used for sauerkraut through lactic fermentation. Cabbage is an important source of vitamin C (Table 3) and provides moderate levels of calcium, iron, phosphorus, and potassium (Adams and Richardson, 1981).

Cabbage is one of the vegetables that have a long storage life. If proper cooling, packing, and storing are practiced, late crop cabbage should keep for 5 to 6 months (Hardenburg et al., 1986). The Danish ball head types and green winter varieties have the longest keeping capability, whereas early crop cabbage has a limited storage life of only 3 to 6 weeks. The storage life of wrinkled-leaved Savoy cabbage is not as long as the smooth-leaved types (Ryall and Lipton, 1979).

Cabbages can be precooled by room cooling, forced-air cooling, or vacuum cooling. After precooling, they should be stored at 0°C with near saturation RH (98–100%) to avoid wilting. Use of perforated polyethylene liners or pallet box covers is beneficial in reducing loss of moisture.

Cabbages are very sensitive to ethylene and should not be stored with ethylene-producing commodities. Ethylene concentrations above 10 $\mu L\ L^{-1}$ are known to cause leaf abscission and loss of green color. For long-term storage, it is advisable to use ethylene scrubbers in the storage room.

Cabbages respond favorably to CA storage. The storage life of late-season cabbage can be extended for several months by using proper combinations of O_2 and CO_2 (Isenberg, 1979). Optimal atmospheric compositions vary with cultivars (Berard, 1985; Bohling and Hansen, 1977; Gariépy et al., 1984a,b; Geeson and Browne, 1980; Isenberg and Sayles, 1969; Raghavan et al., 1984). The recommended ranges for CA storage are 2–3% O_2 plus 3–6% CO_2 (Saltveit, 1993). In general, CA delays cabbage senescence by retarding yellowing, toughening, loss of flavor, and decay (Geeson, 1989). Controlled atmospheres also affect the changes of glucosinolates during storage. Compared to air storage, CA-stored cabbages have more volatile isothiocyanates and goitrin during the early storage period, and less during the late period of storage (Bérard and Chong, 1984).

There are several diseases that can cause losses of cabbages during storage and marketing periods (Ramsey and Smith, 1961). These diseases are bacterial soft rot, gray mold rot, Rhizopus soft rot (*Rhizopus stolonifer*), and watery soft rot.

G. Cabbage, Chinese [Michihili and Napa (*Brassica rapa* L., Pekinensis Group), Pak Choi (*Brassica rapa* L., Chinensis Group)]

Chinese cabbage can be categorized into three closely related types: the Michihili or long, small-diameter head type; the Napa or short, large-diameter head type; and the Pak Choi type, of which the petioles are the main edible portion (Sterrett and Savage, 1986). Despite their differences in appearance, the quality criteria and storage requirements for all three types are similar. The heads of Chinese cabbages should be firm. The petioles and midribs should be white without black specks or other discolorations. The upper part of the outer leaves should be green or dark green, and that of the inner leaves should be light yellow.

The storage life of Chinese cabbage is 2 to 3 months at 0°C with 95–100% RH (Hardenburg et al., 1986; van den Berg and Lentz, 1977). Some cultivars of Chinese cabbage were reported to be susceptible to CI, which causes brown midribs to develop after a prolonged exposure to low temperatures (Apeland, 1984a). The critical chilling temperatures vary with different cultivars. In these cases, the Chinese cabbage should be kept at the lowest nonchilling temperature for prolonged storage.

Controlled atmosphere with 2% O_2 plus 2–5% CO_2 produces good results (Apeland, 1984b; Weichmann, 1977; 1981). Low O_2 (1%) alone is also effective in extending the storage life and inhibiting the loss of chlorophyll, ascorbic acid, and sugars (Wang, 1983). Combined with low temperature, low O_2 storage can extend the storage life of Chinese cabbage to 5 months or more.

Various cultivars of Chinese cabbage contain varying levels of glucosinolates (0.097 to 0.704 g kg^{-1} F.W.) (Lewis and Fenwick, 1988). The degradation products of glucosinolates contribute to the flavors of Brassica vegetables. The amount of glucosinolates in tissues therefore affects the quality of Brassica vegetables (Shattuck and Wang, 1993). Glucosinolates in Chinese cabbage head tissue yield C-5 aglucons, which are converted to isothiocyanates (Williams and Daxenbichler, 1981). Much of the characteristic flavor of Chinese cabbage comes from the isothiocyanates.

Imbalance of mineral nutrients in Chinese cabbage can cause several problems (Takahashi, 1981). Examples include calcium deficiency, which results in rotting of leaf margins, boron deficiency, which causes cracking and browning of the inner surface of midribs, and excessive nitrogen, which induces numerous small black spots. The most important market diseases and disorders in Chinese cabbage are bacterial soft rot, black rot (*Xanthomonas campestris*), and black leaf speck (Ramsey and Smith, 1961).

H. Cauliflower (*Brassica oleracea* L., Botrytis Group)

A high-quality cauliflower should be harvested at proper maturity with compact flower head and white curds. Overmaturity results in loss of compactness with loose and spreading curds, and is undesirable.

Cauliflower can be precooled by hydrocooling or vacuum cooling. Hydrocooling can lower the cauliflower temperature from 21°C to 5°C in 20 min in 1°C water, while vacuum cooling takes about 30 min to obtain an equivalent cooling (Stewart and Barger, 1961). At 0°C and >95% RH, cauliflower can be stored satisfactorily for 3 to 4 weeks.

Cauliflower is sensitive to both low O_2 and high CO_2 injuries (Lipton et al., 1967; Lipton and Harris, 1976). These injuries induce off-odors, off-flavors, and excessive softening after cooking. Tomkins and Sutherland (1989), however, reported that 2% O_2 plus 5% CO_2 reduced the incidence of soft rot and black spotting, and the storage life was extended to 47 days at 1°C compared to 27 days in air. The cooking quality of curds was acceptable after aeration of the CA-stored curds for 1.5 to 3 h. Film overwrap is beneficial for reducing moisture loss and wilting, but adequate perforation should be used to prevent accumulation of excessive CO_2 or depletion of O_2.

The most important pathological problem in cauliflower is bacterial soft rot, which can infect both leaves and curds. The microorganism enters through stomata of leaves and causes specking, spotting, and blotching of the green leaves. The disease is also likely to invade overmature curds and those having mechanical injuries. Lesions on the curds appear as small gray to brown spots. The development of the disease can be retarded by temperatures near 0°C (Ramsey and Smith, 1961). Other diseases that can occur in cauliflower include bacterial leaf spot (*Pseudomonas maculicola*), downy mildew, brown rot (*Alternaria brassicae*), gray mold rot, ring spot (*Mycosphaerella brassicicola*), and watery soft rot (Ramsey and Smith, 1961).

I. Celery [*Apium graveolens* L. var. dulce (Mill.) Pers.]

Desirable celery should be crispy and fresh-looking with a green color. The petioles should be straight and compact. Celery should be harvested before the outer stalks become pithy or yellow. For better storage, celery ought to be cut with a small portion of the root system attached.

Celery is commonly precooled with hydrocooling or forced-air cooling. Vacuum cooling is also widely used, especially when celery is packed in corrugated cartons. Water should be sprinkled during vacuum cooling to minimize moisture loss from the stalks. A thorough cooling is necessary to bring the temperature of the petioles down near 0°C, particularly when hydrocooling is used, otherwise microorganisms grow rapidly in wet and warm celery.

Since celery is not sensitive to chilling, the recommended storage temperature is 0°C (Hardenburg et al., 1986). Also, since wilting is a major cause of deterioration, the RH of the storage environment should be maintained at 98–100% (Ryall and Lipton, 1979). Under these conditions, celery can be kept for 2 to 3 months.

A phytoalexin, psoralen (linear furanocoumarin), has been reported to be associated with resistance to pathogens in celery (Beier and Oertli, 1983). The amount of psoralen in celery changes during storage (Chaudhary et al., 1985). Treatment with gibberellic acid (GA) has been shown to increase resistance to pathogens by maintaining high levels of (+) marmesin, the precursor of psoralens, in celery (Afek et al., 1995). A black discoloration of the stalks in a striped pattern along the vascular strands may develop after cold storage (Smith et al., 1982; Walsh et al., 1985). The presence of ethylene or prestorage treatment with sodium hypochlorite has no effect on the occurrence of this disorder. The disorder can be controlled by an atmosphere of 3% O_2 plus 2% CO_2, however (Walsh et al., 1985).

Gray mold rot and watery soft rot are two of the major diseases attacking celery. Gray mold rot is probably the principal cause of loss of celery stored longer than 4 weeks (Smith et al., 1982). Lesions appear watersoaked initially and tend to progress lengthwise along the petioles. The decayed tissues change to a grayish-buff and eventually form masses of grayish-brown spores. This disease develops slowly at 0°C; therefore, temperatures during transit and storage should be kept as close to 0°C as possible. Watery soft rot is also known as pink rot. The affected tissues are generally soft and light brown with a pinkish-brown border. The growth of both gray mold rot and watery soft rot can be suppressed by a storage atmosphere containing 1.5% O_2 plus 7.5% CO_2 (Reyes, 1988; Reyes and Smith, 1986; Smith and Reyes, 1988). Other diseases affecting celery include bacterial blight, bacterial soft rot, brown spot, early and late blight, and mosaics virus (Smith et al., 1982).

J. Chicory, Witloof (*Cichorium intybus* L.)

Fresh Witloof chicory should be firm and light yellow without browning discoloration on the margins. Marginal leaf browning is a sign of senescence that occurs after 2 to 4 weeks at 2°C, 1 to 2 weeks at 5°C, and 1 week at 15°C (Herregods, 1971).

Harvested chicory should be stored at 0°C with 95% or higher RH (Ryall and Lipton, 1979). Overwrapping with perforated film is helpful in reducing moisture loss and maintaining quality. Witloof chicory can be stored twice as long at 0°C in 3–4% O_2 plus 4–5% CO_2 compared to storage in air. Controlled atmosphere storage is also effective in delaying greening of the leaf tips in light and opening of the heads. Witloof chicory can be infected with bacterial soft rot (*Pseudomonas marginalis*) or watery soft rot. These diseases cause disintegration of tissues, which become soft and watery with an unpleasant odor. Maintaining sanitation of the handling areas and prompt cooling to below 4°C can reduce the incidence of decay.

K. Endive and Escarole (*Cichorium endiva* L.)

Both endive and escarole are leafy salad greens that belong to the same species. Endive has narrow, curled, and finely divided leaves, whereas escarole has thick, broad, twisted, and wavy leaves. These salad vegetables should be green, fresh, crisp, and free from blemishes.

Endive and escarole can be vacuum cooled or hydrocooled and then stored at 0°C to maintain their fresh appearance and reduce decay (Ryall and Lipton, 1979). Relative humidity in storage rooms should be kept above 95% to prevent wilting (Hardenburg et al., 1986).

The serious transit and market diseases of endive and escarole are gray mold rot, bacterial soft rot (*Pseudomonas marginalis*), watery soft rot, aster yellows (a mycoplasma), and lettuce mosaic virus (Moline and Lipton, 1987).

L. Green Onions (*Allium cepa* L.)

The leaves of green onions should be straight, crisp, and green without discoloration. Green onions are very perishable and must be marketed promptly after harvest.

After harvest, green onions can be vacuum cooled to remove field heat. Packaging with perforated film bags is helpful in reducing wilting and preventing breaking of leaf stalks. Wilting in green onions is noticeable when 15% weight is lost (Hruschka, 1974). For best quality maintenance, green onions should be kept at 0°C and 95–100% RH throughout storage and marketing (Hardenburg et al., 1986). A CA of 1% O_2 plus 5% CO_2 at 0°C has been reported to maintain green onions in good quality for 9 weeks (Hruschka, 1974).

Some diseases that affect dry onions can also affect green onions (Hruschka, 1974; Smith et al., 1982). Gray mold rot (*Botrytis* spp.) has been reported to cause losses of green onions in the market. Green onions are also susceptible to smut (*Urocystis cepulae* Frost), a disease that is characterized by dark-colored streaks on the leaves and bulbs (Smith et al., 1982). The affected areas are filled with greenish-black, powdery masses of spores. Green onions infected with smut are occasionally found on the market. The diseased green onions can be culled out during the postharvest packing process to avoid contamination of others and to maintain wholesomeness of the product.

M. Greens, Leafy {Beet Greens [*Beta vulgaris* L. ssp. vulgaris], Collards and Kale [*Brassica oleracea* L., Acephala Group], Mustard Greens [*Brassica juncea* (L.) Czerniak], Turnip Greens [*Brassica rapa* L., Rapifera Group], Swiss Chard [*Beta vulgaris* L., var. flavescens (Lam.) Lam.], Water Convolvulus (*Ipomoea aquatica* Forsk.)}

Freshness is the main quality factor desired for leafy greens. Freedom from decay, mechanical damage, and insect injury are all required to constitute good quality. Tenderness, cleanliness, and uniformity of green color are also desirable.

Leafy vegetables usually have large surfaces and are characterized by high respiration and transpiration rates. They lose water readily and are highly perishable. After harvest, leafy vegetables should be cooled without delay to remove field heat. Because of their large surface-to-volume ratio, leafy greens can be effectively cooled with vacuum cooling or Hydro-Vac cooling. Hydrocooling is also satisfactory if water temperature can be maintained near 0°C. Following precooling, the commodities should be kept cold either by package icing or by mechanical refrigeration and should be transported by refrigerated vehicles.

Except for water convolvulus, which is chilling-sensitive, all the other leafy greens mentioned here should be kept at 0°C. Water convolvulus (also called water spinach, kong xin cai, or ung choi) is a popular tropical leafy vegetable. It can be injured by chilling temperatures below 9°C within 2 to 4 days of storage (Hirata et al., 1983; 1987; Paull, 1990). Symptoms of CI are browning and water-soaked appearance of the leaves.

All leafy vegetables are highly subject to wilting. They should therefore be stored in an environment with high RH (>95%) to minimize water loss. Package icing minimizes water loss by helping to maintain high humidity within packages. Storage life of leafy greens such as kale can be extended if packaged in perforated moisture-retentive film bags (Hruschka, 1971).

Ethylene hastens yellowing and senescence, and decreases the shelf life of all leafy greens. Exposure to ethylene should therefore be avoided and leafy greens should not be stored with ethylene-producing crops. Modified atmosphere or CA tends to retard yellowing and maintain the quality of leafy greens. The recommendation for CA storage of spinach is 7–10% O_2 plus 5–10% CO_2 (Saltveit, 1993).

Some common diseases of spinach and other leafy greens on the market are bacterial soft rot, downy mildew (*Peronospora effusa*), and white rust (*Albugo occidentalis*) (Moline and Lipton, 1987).

N. Kohlrabi (*Brassica oleracea* L., Gongylodes Group)

The edible portion of kohlrabi is its fleshy stem. The most important factors determining its quality are tenderness and toughness of the texture, and freedom from blemishes, wilting, and decay.

The optimal storage conditions for topped kohlrabi are similar to those for topped carrots. Kohlrabi should be cooled to below 5°C soon after harvest and stored at 0°C with a high relative humidity (preferably 98–100%) to prevent toughing and shriveling of the texture (Hardenburg et al., 1986; Ryall and Lipton, 1979). Under these conditions, topped kohlrabi can be stored for 2 to 3 months. Kohlrabi with leaves, however, can only be kept for about 2 weeks at 0°C. Since high humidity is required for kohlrabi storage, packaging in perforated film is beneficial for maintaining the quality of kohlrabi.

The most common diseases that can occur during storage of kohlrabi are bacterial soft rot and black rot.

O. Leeks (*Allium ampeloprasum* Tausch.)

The quality criteria and storage conditions of leeks are similar to those for green onions. The leaves of leeks should be green and the base of the stalks should be white without discoloration.

Leeks should be cooled promptly after harvest by hydrocooling, vacuum cooling, or crushed ice. They should keep satisfactorily for 2 to 3 months in storage at 0°C with 95–100% RH (Hardenburg et al., 1986). High humidity is important to prevent wilting. Losses occurred in storage with 90–95% RH are much higher than those with 98–100% RH (van den Berg and Lentz, 1977). Consumer-unit packaged leeks from stock that was stored in polyethylene-lined wooden crates had a longer storage life than that from unlined wooden crates, primarily because of less moisture loss (Hruschka, 1978). Low temperature and high humidity also retard elongation of leek stalks. Leeks stored in polyethylene-lined crates elongated less than 1% per week at 0°C under crushed ice, but 22% per week at 10°C (Hruschka, 1978). Respiration and heat evolution rates for leeks and green onions are very similar at various temperatures. At 21°C, leeks produce 110 mg CO_2 $kg^{-1}h^{-1}$ and 28 mJ of heat $ton^{-1}d^{-1}$, which is about eight times the rates for leeks held at 0°C (Hruschka, 1978).

Considerable improvement of the quality of leeks can be obtained by using CA storage. An atmosphere of 2% O_2 plus 2–5% CO_2 has been shown to be better than ambient air to preserve the green color of leaves and the white color and firmness of stems, and to reduce the development of decay (Goffings and Herregods, 1989).

Leeks are susceptible to many diseases that also affect onions. Most rot during storage is caused by bacterial soft rot, gray mold rot (*Botrytis allii*), blue mold rot (*Penicillium* spp.), and smudge (*Colletotrichum circinans*) (Smith et al., 1982). The best defense against these diseases during the postharvest period is to maintain adequate refrigeration.

P. Lettuce (*Lactuca sativa* L.)

Lettuce on the market can be classified into four types: (a) iceberg or crisphead, (b) butterhead, (c) romaine, and (d) looseleaf. Turgidity, firmness, and freedom from physiological disorders, mechanical damage, and decay are the desired attributes for iceberg or butterhead lettuce. For romaine or looseleaf lettuce, freshness, tenderness, and freedom from broken or discolored leaves, insect injury, and wilting are factors of good quality.

All lettuce should be precooled to near 0°C soon after harvest. A delay of more than 9 h between harvest and precooling increases subsequent yellowing and wilting (Lipton and Barger, 1965). The most common precooling method for crisphead and leaf lettuce is vacuum cooling. Hydrocooling is also effective. Care should be taken to avoid mechanical damage to the leaves in the cooling process, however. Thorough precooling and subsequent storage at 0°C with 98–100% RH are essential in maintaining freshness of these salad greens (Hardenburg et al., 1986; Ryall and Lipton, 1983). Packaging of lettuce with perforated polyethylene films reduces weight loss, butt discoloration, and other physiological disorders (Hinsch et al., 1976; Parsons et al., 1960; Stewart et al., 1967; Wang et al., 1984).

Controlled atmosphere storage improves postharvest quality of lettuce (Haginuma et al., 1985; Lipton, 1967). Crisphead lettuce, however, is sensitive to low O_2 (<1%) and high CO_2 (>2.5%). High CO_2 levels cause brown stain on midribs of crisphead lettuce (Brecht, 1973; Stewart and Uota, 1971). The induction of brown stain by elevated CO_2 atmospheres is related to the accumulation and oxidation of soluble phenolic compounds (Ke and Saltveit, 1989a; Siriphanich and Kader, 1985). Lettuce harvested in the morning is more susceptible to high CO_2 injury than that harvested in the afternoon (Forney and Austin, 1988). Romaine lettuce seems to be more tolerant to high CO_2 levels than crisphead lettuce. An atmosphere of 2–10% O_2 plus 5% CO_2 delays the deterioration of romaine lettuce (Aharoni and Ben-Yehoshua, 1973). Storage of romaine lettuce at CO_2 concentrations higher than 15%, however, results in brown, sunken patches on the green leaves (Lipton, 1987).

Lettuce is subject to a number of physiological disorders during the postharvest period (Lipton et al., 1972, Table 5). Among them, russet spotting is one of the most serious disorders (Morris et al., 1978). Exposure to ethylene has been found to be the primary factor in the occurrence and severity of russet spotting (Rood, 1956). Russet spots may occur anywhere in the lettuce except on the heart leaves (Lipton et al., 1972). Ethylene-induced phenylalanine ammonia-lyase activity may be related to the development of russet spotting (Hyodo et al., 1978). Postharvest application of calcium, potassium, or indole-3-acetic acid can inhibit the development of this disorder (Ke and Saltveit, 1986; 1988). Controlled atmosphere storage also reduces russet spotting in crisphead lettuce (Lipton, 1967). The reduction of russet spotting development by low-O_2 atmospheres is related to the inhibition of phenolic metabolism and indole-3-acetic acid oxidase activity (Ke and Saltveit, 1989b). Other physiological disorders include pink rib, butt discoloration, tipburn, internal rib necrosis, and rusty-brown discoloration (Lipton, 1972; Moline and Lipton, 1987).

Diseases that can affect lettuce include bacterial soft rots (*Pseudomonas* and *Erwinia* spp.), big vein (*Olipidium brassicae*), downy mildew (*Bremia lactucae*), gray mold rot, and watery soft rot (Moline and Lipton, 1987).

Q. Parsley [*Petroselinum crispum* (Mill.) A.W. Hill var. crispum]

Good quality parsley should be green and turgid. Parsley loses moisture and wilts easily; therefore, it should be stored under high RH (95–100%) and low temperature (0°C). Packaging in perforated polyethylene bags and storing at 0°C in cartons or crates with container and top ice greatly increases the storage and shelf life of parsley (Hruschka and Wang, 1979). Packaged parsley also retains more ascorbic acid than the naked bunches, particularly at warm temperatures. The respiration rate of parsley increases with storage temperature, but decreases with time in storage.

Parsley can be kept in good condition for 3 to 4 months at 0°C. Controlled atmosphere using 10% O_2 plus 11% CO_2 can further lengthen the storage life (Apeland, 1971).

The most serious transit and market diseases of parsley are bacterial soft rot and watery soft rot (Smith et al., 1982). Cooling quickly after harvest and maintaining a cold chain near 0°C is the best way to inhibit these market diseases.

R. Rhubarb (*Rheum rhabarbarum* L.)

Freshly harvested rhubarb stalks should be straight and crisp and free from blemishes and decay. A major cause of postharvest deterioration is leaf blade breakdown, therefore leaf blades should be removed and discarded before packaging and shipping the stalks to market. Removal of the leaves can eliminate leaf blade rot caused by *Botrytis* spp., reduce shipping weight, and decrease moisture loss during marketing. A small portion (5 to 6 mm) of leaf can be left on the stalk to lessen the possibility of the petiole splitting, however.

Rhubarb stalks can be adequately precooled by room cooling or hydrocooling. Following precooling, rhubarb should be kept at 0°C and high RH (95% or above). In addition, rhubarb should be protected from moisture loss by storing it in crates lined with perforated polyethylene film and then packaging it in perforated moisture-proof bags to maintain freshness during retailing (Hruschka, 1967). Packaged, debladed rhubarb stalks remain in acceptable condition at 0°C for 4 weeks plus 1 day at 21°C. The storage life is reduced to 2 weeks when the stalks are cut into 25-cm-long pieces, and 1 week for 2.5-cm-long pieces (Hruschka, 1967). The respiration rate of 2.5-cm-long pieces is about twice as high as that of a whole stalk. The respiration rate at 21°C is about twice that at 10°C and about four times that at 0°C (Hruschka, 1967).

Rhubarb can be infected by anthracnose (*Colletotrichum erumpens*), bacterial soft rot, gray mold rot (*Botrytis* spp.), and Phytophthera rot (Moline and Lipton, 1987).

S. Watercress (*Nasturtium officinale* R. Br.)

Watercress is a desirable salad and garnish item. The leaves should look fresh, turgid, and green. Watercress is highly perishable and should be promptly precooled by hydrocooling or vacuum cooling, then stored at 0°C with 95 to 100% RH. Holding watercress bunches in perforated film packages provides significantly longer storage and shelf life than holding the bunches naked. At 0°C, watercress keeps well for up to 4 weeks in perforated polyethylene bags, but only 4 days in naked bunches (Hruschka and Wang, 1979).

Storage temperature greatly affects the respiration rate of watercress. While the respiration rate of freshly harvested watercress is 15 mg CO_2 $kg^{-1}h^{-1}$ at 0°C, it increases three times at 5°C, 10 times at 15°C, and 20 times at 20°C (Hruschka and Wang, 1979).

Watercress can be infected by diseases that commonly occur in leafy crucifers, including Alternaria leaf spot (*Alternaria brassicae*), bacterial soft rot, black rot, and downy mildew (Ryall and Lipton, 1979).

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